Poultry Litter Ash as a Phosphorus Source for Corn

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ABSTRACT

As the expanding world population places pressure on the poultry industry to meet consumption demands, heightened poultry litter (PL) production increases volumes for land application. Repeated PL applications within localized distances of poultry operations creates nutrient concentrated areas posing a threat to ecosystems. Poultry litter ash (PLA), a co-product from manure-to-energy systems, is a promising solution addressing: transportation logistics, repurposing PL nutrients, and offers dual purpose as a fertilizer and an energy source. The overarching project goal is to prove or disprove PLA as a comparable fertilizer. Thermo-conversion systems alter PLA nutrient solubility; therefore, the first objective is to determine solubility fractions of four PLA (Fluidized Bed Bulk, Combustion Mix, Fluidized Bed Fly, and Ash Coated Urea) and P fertilizers (poultry litter and triple super phosphate). Phosphorus sources were extracted sequentially using deionized water, $NaHCO_3$, NaOH, HCl, and finally acid digested with HNO_3 followed by analysis via ICP-AES. Water extraction represented soluble P (Ps%) whereas $NaHCO_3$ signified labile inorganic P (Pi%). Phosphorus extracted by NaOH and HCl is categorized as non-labile inorganic or bound P (Pb%). The second objective is to compare nutrient availability of phosphorus (P) of PLA with industry standard P fertilizers and subsequent effect on corn yield. Experimental design included 13 fertilizer treatments arranged in a two factor randomized complete block design with source and rates as factors in a low P environment. Overall, nutrient solubility and plant availability is paramount for evaluating PLA derived co-products as grain fertilizers.

INTRODUCTION

- Virginia ranks 6th and 14th nationally for turkey and broiler production totaling 5,160,05 turkeys and 38,386,310 broilers (USDA, 2012), respectively.
- Recycling poultry litter (PL) nutrients into poultry litter ash (PLA) serves a dual purpose as an energy and fertilizer source.
- Poultry litter ash results in phosphorus (P) concentrations four to ten times greater than poultry litter (Reiter and Middleton, 2016).
- High temperatures of thermo-conversion systems effectively recycle PL but reduce PLA nutrient solubility.
- Decreased PLA solubility is identified as a potential agronomic obstacle (Codling, 2006; Pagliari et al., 2010).

OBJECTIVES

- To prove or disprove PLA as a comparable P fertilizer.
  - Determine P solubility fractions from PLA and co-products compared to industry standard triple super phosphate and PL.
  - Compare effects of PLA and P-industry standard fertilizers on corn productivity.

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MATERIALS AND METHODS

Sequential Solubility Extractions

- Poultry litter ashes and P fertilizer sources were sequentially extracted (Dou et al., 2000; Codling, 2006).
- Sequential extractants included:
  - 30 mL Deionized H_20
  - 30 mL 0.5M $NaHCO_3$
  - 30 mL 0.1 M NaOH
  - 30 mL 1 M HCl
  - Followed by Acid Digestion using EPA 3050B
- Extractions analyzed via ICP-AES for P concentrations.
- Mean separation completed using Fisher's Protected LSD at 10% significance level.

Field Study

- Study was initiated in April 2017 in Essex County, Virginia.
- Pamunkey fine sandy loam (Fine-loamy, mixed, semiactive, thermic Ultilic Hapludalfs).
- At planting, soil test concentrations were:
  - 8 mg P kg $^{-1}$ (Low)
  - 102 mg K kg $^{-1}$ (Medium)
  - 103 mg Mg kg $^{-1}$ (High)
  - 465 mg Ca kg $^{-1}$ (Medium-)
  - pH= 6.6 (1:1 soil:water)
  - Cation Exchange Capacity= 2.7 meq 100g $^{-1}$
- Plots were 3 m by 12.2 m, consisting of four replications of 13 fertilizer treatments arranged in a two-factor randomized complete block design with source and rate as factors.
  - Fertilizer Rates: 0, 22, 45, and 67 kg P_20_5 ha $^{-1}$
  - Sources: Control, Triple super phosphate (TSP), Poultry litter, FB bulk and C. Mix.
- Fertilizer treatments were applied based on soil testing recommendations from Virginia Cooperative Extension.
- Corn ear leaf plant tissue was collected, dried, ground, and digested via EPA 3050B and analysed for total P.
- Treatment mean separation completed using Fisher's Protected LSD at 10% significant level.

ASH PRODUCTS

Figure 1 PLA and Co-Product Analysis

Ash Product	% Total N (TKN)	% P_2O_5	% K_20	pH
Fluidized Bed Bulk (*FB Bulk*)	0.04	12.1	8.2	10.4
Fluidized Bed Fly (*FB Fly*)	0.3	12.9	14.9	9.3
Combustion Mix (*C. Mix*)	0.3	17.4	16.8	11.7
Ash Coated Urea (*ACU*)	37.7	2.1	2.4	8.6
Poultry Litter (*PL*)	3.4	1.8	2.2	7.7
Triple Super Phosphate (*TSP*)	0	46	0	0

RESULTS AND DISCUSSION

Sequential Solubility

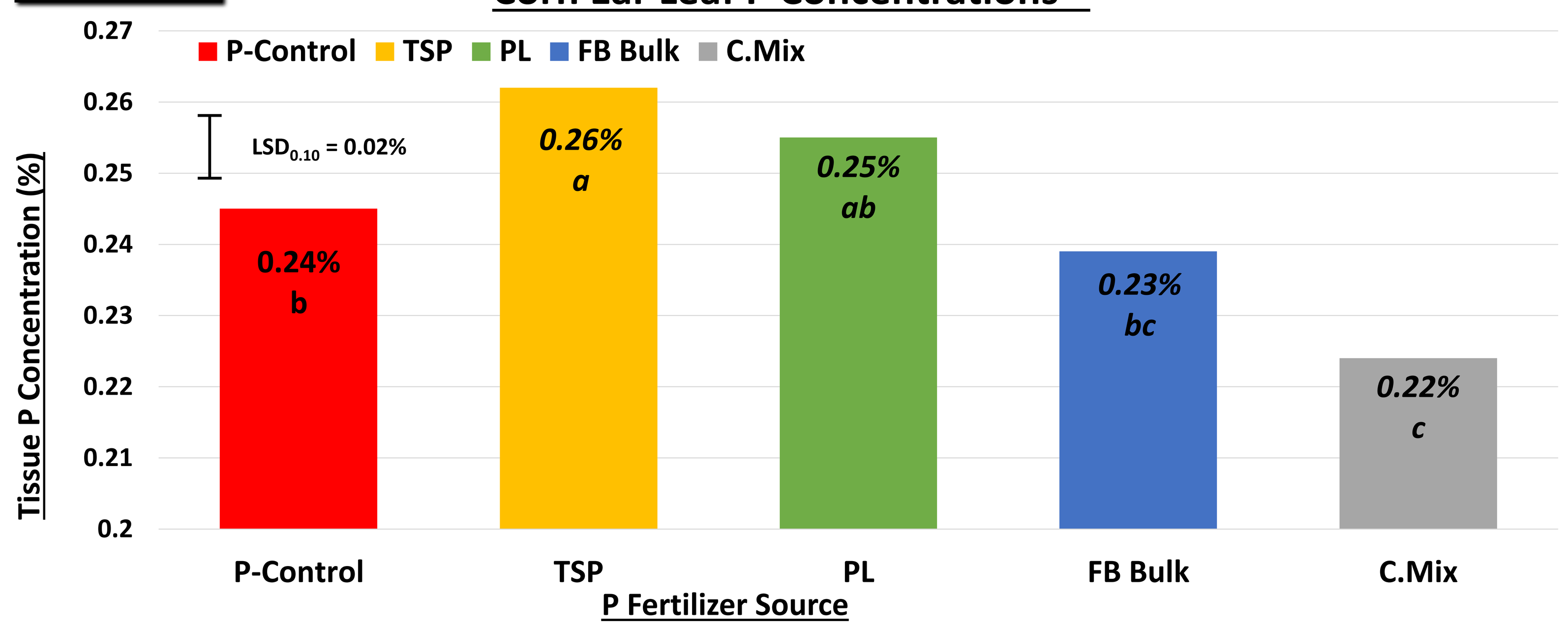
- Largest inorganic phosphorus fraction in PLA was found in the bound (Pb) portions.
- Amount of inorganic P from PLA (greatest to least): HCl ***(Bound)*** > NaOH ***(Bound)*** > H_20 ***(Soluble)*** > $NaHCO_3$ ***(Labile)***
- Overall FB Bulk (0.95%), FB Fly (1.54%) , and C. Mix (0.49%) water solubility was significantly less than TSP (74.51%) and PL (33.38%). ($LSD_{0.10}$=6.23%)
- Ash coated urea, coated with FB Fly ash, had a significantly higher water soluble P percentage of 9.10% than other ash products due to smaller ash particle size needed for coating process. ($LSD_{0.10}$=6.23%)

Figure 2 PLA Sequential Solubility Extractions

	Inorganic P	Bound P	Total P	Percent Water Soluble P in Total P
Source	Pi % ($NaHCO_3$)	Pb % (NaOH & HCl)	Pt %	Ps % (H_2O)
TSP	15.54 a	5.33 b	20.87 a	74.51 a
PL	0.63 b	1.26 c	1.89 d	33.38 b
FB Bulk	0.04 c	4.68 b	4.73 c	0.95 d
FB Fly	0.08 c	5.37 b	5.45 c	1.54 d
C. Mix	0.02 c	6.54 a	6.57 b	0.49 d
ACU	0.05 c	0.59 c	0.65 e	9.10 c
*LSD	0.3	0.87	0.86	6.23

Figure 3

Corn Ear Leaf P Concentrations *



Interaction of source by rate was not significant; therefore, data for P source are pooled over P rate.

Tissue Concentrations:

- Triple super phosphate (TSP) resulted in significantly higher corn ear leaf P (0.26%) concentrations than FB Bulk (0.24%) and C. Mix (0.22%). ($LSD_{0.10}$=0.02%)
- Triple super phosphate and PL had sufficient P concentrations at corn ear leaf sampling (0.25-0.45%).
- No significant difference in corn ear leaf P concentrations between poultry litter (PL) (0.25%), FB Bulk (0.23%), and P-Control (0.24%); however P-Control and PL was significantly higher than C. Mix (0.22%). ($LSD_{0.10}$=0.02%)
- Averaged over source, P corn ear leaf concentrations were similar following rates of 45 and 67 kg P_20_5 ha $^{-1}$ ($LSD_{0.10}$=0.02%). (Data not shown)

Yield:

- There was no significant treatment effect on corn yield among all P sources (p =0.71) and P rates (p=0.21).
- Corn yield averaged 5,461.8 kg ha $^{-1}$.

CONCLUSIONS

- Overall, poultry litter ash solubility (Ps%) is significantly less than industry standard P sources and presents an obstacle for utilizing PLA as comparable P fertilizer source.
- FB Bulk ash and PL resulted in statistically similar corn ear leaf concentrations and corn yield as PL.

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